Agricultural Sciences Journal
Available online at http://asj.mnsuam.edu.pk/index.php
ISSN 2707-9716 Print
ISSN 2707-9724 Online
https://doi.org/10.56520/asj.v6i1.365

Review Article

POWDERY MILDEW OF MANGO: CURRENT STATUS, PERSPECTIVE AND EMERGING TOOLS FOR MANAGEMENT

Shahid Iqbal[1,2*],Muhammad Atiq[2*], Muhammad Fayyaz[1] , Muhammad Zakria[1], Nasir Ahmed Rajput[2], Aasma[1], Ghalib Ayaz Kachelo[2, 3], Ijaz Ahmad[4], Muhammad Usman[2], Asim Mehmood[1]

[1]*Crop Diseases Research Institute, National Agriculture Research Center, PARC, Islamabad, Pakistan*
[2]*Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan*
[3]*Crop Diseases Research Institute, Southern Zone Agriculture Research Center, PARC, Karachi, Pakistan*
[4]*Pulses Programme, Crop Sciences Institute, National Agriculture Research Center, PARC Islamabad, Pakistan*
**Corresponding author:* shahidjahanian1@gmail.com, muhammad.atiq@uaf.edu.pk

Abstract

Mango (*Mangifera indica*) is an important fruit crop that belongs to the family Anacardiacae. It is considered the most delicious fruit cultivated around the tropical and sub-tropical regions of the world. In Pakistan, mango ranked second in terms of production after citrus. It plays a vital role in enriching the economy of the country. However, its production is hampered by several biotic and abiotic stresses. Fungal pathogens are a major threat to the successful production of mangoes. Powdery mildew, caused by the fungus *Pseudoidium anacardii* (formerly *Oidium mangifera*), poses a significant threat to mango crops worldwide, leading to substantial losses in yield. Previous studies confirmed that around 20-25% of yield losses in mango production occur due to powdery mildew disease, with 100% of disease incidence in major mango-growing regions. The most severe losses occur when flowering and growth flushes become infected, especially during cool and dry weather conditions. Optimal disease development typically happens within a temperature range of 11–14 °C minimum and 27–31 °C maximum, coupled with relative humidity levels of 64–72%. Despite the widespread impact, and influence of climate change, losses are increasing day by day. There is a lack of comprehensive research on the symptoms, biology, and control measures. Control is difficult due to the emergence of resistant strains and the varying levels of susceptibility of mango varieties. Therefore, it is crucial to implement integrated management techniques to control powdery mildew. To address this issue, various approaches, such as chemical control, biological control, and Nanotechnology are being employed as management strategies. This review included a brief explanation of different management strategies used against the powdery mildew of mango concerning previous studies.

Keywords: *Nanotechnological Approaches, Oidium Mangifera, Antifungal Potential, Disease Incidence*
(Received: 03-Jan-2024 Accepted: 06-Apr-2024) Cite as: Iqbal. S., Atiq. M., Fayyaz. M., Zakria. M., Rajput. N. A., Aasma., Kachelo. G. A., Ahmad. I., Uaman. M., Mehmood. A., 2024 Powdery mildew of mango: current status, perspective and emerging tools for management. Agric. Sci. J. 6(1): 92-101.

1. INTRODUCTION

Mango (*Mangifera indica*) holds a prominent position among fruit crops worldwide, including Pakistan. Its cultivation dates back to four centuries ago in South Asia (Yadav and Singh, 2017). Known as "The king of fruits," mango is not only delicious but also highly nutritious and valuable. Mango leaves contain a rich array of minerals (nitrogen, phosphorus, potassium, sodium, iron, calcium, and magnesium), vitamins (A, B, E, C), and proteins. In traditional medicine, mango leaf extracts have been used to treat various ailments such as diarrhea, diabetes, bronchitis, kidney issues, scabies, asthma, and respiratory problems (Shah et al., 2010; Kulkarni et al., 2014). Furthermore, mango cultivation plays a crucial role in boosting the country's economy, contributing an annual export value of up to $36.66 million (Pavitra et al., 2021).

Mango is cultivated in a significant area worldwide, while in Pakistan; it is produced on 158.659 thousand hectares annually, yielding 1.8 million tons of mango (MNSFR, 2020). Mango thrives in deep, well-drained sandy loam soils with a pH range of 5.5-5.8, while soils with sticky clay, hardpan, and waterlogged conditions should be avoided (Bally and Dillon, 2018). The provinces of Punjab and Sindh in Pakistan provide an ideal and favorable environment for mango cultivation, contributing the most to mango production in the country (MNSFR, 2020). Popular mango varieties cultivated in Pakistan are Chaunsa, Langra, Sindhri, Anwer Ratol, and Dussehri, which not only dominate the local market but are also considered as high-demanding fruit crops in the international market. Multan, known as the heart of mango, is the 6th largest mango-producing city in the country (Tahir et al., 2012). However, the production of mango faces challenges from various biotic stresses (fungal, bacterial, viral, and nematode infections) and abiotic stresses (extreme temperatures, high rainfall, relative humidity, and wind speed). Among fungal diseases, powdery mildew caused by *Oidium mangifera* poses a significant threat to mango production, resulting in complete yield losses in different mango-growing areas worldwide (Ploetz, 1999). Powdery mildew primarily affects young fruits, mango clusters, and leaves of highly susceptible mango cultivars, and it also facilitates the development of anthracnose through the injuries it causes (Sinha et al., 2002). The development of the disease is influenced by epidemiological factors and the interaction between the host and pathogen. Conidia production is highest at a temperature of 25°C and relative humidity of 40-60%, and symptoms typically appear within 58 days of infection (Naqvi et al., 2014). The economic importance of this disease is significant due to its severe threat to the mango industry. However, comprehensive knowledge about the disease is essential to effectively manage it and ensure fruitful mango yields. This manuscript aims to provide insights into the pathogen profile, disease history, symptomology, geographical distribution of the disease and validated approaches to combat the pathogen causing powdery mildew in mango.

2. Biology of Pathogen

Powdery mildew is a fungal disease of mango, caused by an obligate pathogen *Oidium mangifera* which was recently named *Pseudoidium anacardii*. After a long controversy, this fungus was named *Oidium Mangifera* Berthet as initially the fungus was recognized as *Erysiphae cichoracearum* belonging to the *Erysiphae polygoni* group due to the development of orbicular haustoria and the fashion of germination of conidia. The characteristic and distinguished morphological parameters of fungi have been described by several researchers in detail (Akhtar et al., 1999). Its mycelium is composed of hyaline, ectotype, and septate hyphae (4.1–8.2 µm), and conidiogenious cells (27.4–40.0 µm). Conidia are elongated to oblong in shape, single cellular, thin-walled, and/or aseptate (Singh, 2000). Molecular studies based on rDNA ITS regions stated its links among anamorphic Erysiphales and their associated teleomorphs (Cunnington et al., 2003). PCR primer for ribosomal DNA internal transcribed spacer increased specificity in 12 tested genera even in contaminated fungi. Herbarium specimens of telomorphic and anamorphic materials yielded DNA for amplification. Sequencing of 25 Internal transcribed spacers from anamorphic specimens was done thereby indicating that correct matches have been made (Cunnington et al., 2003).

3. Taxonomic Status

Oidium mangifera causing powdery mildew of mango is an obligate parasite. It belongs to the order Ersysiphales and its family is Erysiphaceae. The *Oidium mangifera* is similar to the pathogen that induces powdery mildew in other crops like oak. However, some differences have been observed as conidiophores number is 2 in O. mangifera infecting mango crop while 3-5 conidiophores are present in the case of oak. For the first time, the causing agent was found to be asexually (anamorph) and given the name of *Oidium mangifera* Berthet. Later on, it was renamed as *Pseudoidium anacardii* (Braun and Cook, 2012). Additionally, recent studies of its rDNA suggest that it is conspecific with *Erysiphae alphitoides*, the etiological agent of Powdery mildew of oak in Europe (Mougou et al., 2008).

4. Geographical Distribution of the Disease

Powdery mildew is an economically important disease of mango prevailing throughout the world including Pakistan. Nelson (2008) reported that in the Indian sub-continent, this disease was present before 1874. However, its prime origin is Brazil and it was recorded first time in 1914 by Berthet (Briton Jones, 1923). Later on, it has been reported in various countries of Africa (Egypt, Tanzania, Congo, Kenya, Ethiopia, South Africa, and Rhodesia), Asia (Pakistan, India, Sri Lanka, Nepal, Burma, Bangladesh), Middle East (Iran, Turkey, Israel, Lebanon, Greece Palestine), America (Florida, Cuba, California, Brazil, Peru, Colombia, Venezuela, and Mexico) and Australia (Wager, 1937; Fields, 1945; Reichert and Palti, 1951; Ruehle and Ledin, 1956; Singh, 1960; Rodrigues and Figueroa, 1963; Brodrick, 1971; Prakash and Raoof, 1994; Felix-Gastelum et al., 2013). From India, the disease was first reported in Maharashtra (McRae, 1924), Uttar Pradesh (Kulkarni, 1924) Karnataka (Galloway, 1935), and Hyderabad (Uppal, 1937) while in Pakistan epidemics of powdery mildew were noticed in Sindh (Jiskani et al., 2007) and in Punjab (Sattar, 1946).

5. Symptomology of Disease

Powdery mildew of mango appeared on new flushes of leaves before flowering and fruit set. The presence of a whitish powdery mass on young leaves and inflorescence are the characteristic symptoms of the disease. Moreover, the flowers within diseased inflorescence persist un-fertile and fall off ahead of maturity (Lonsdale and Kotze, 1993a; Wagle, 1928). The fungus primarily infects fresh tissues of the leaves and stalk, flower scale as well as the buds of flowers and fruits at early stages (Singh, 1960). Purplish brown spots develop on mature leaves while fruits are deformed, reduced in size as well as dropped at the pea stage.

6. Epidemiology of disease

Epidemiology factors and plant-pathogen interaction are key components for the initiation of disease. Temperature (20-25 °C) and moderate relative humidity are more conducive conditions for conidial germination and disease development (Sinha et al., 2002; Prakash and Raoof, 1994). Moreover, the establishment of infection and epidemiology of the disease is influenced by various factors like host plants, dormant mycelium, asexual form, tissue specificity, and environmental conditions. According to the findings of Singh (2000) and Pathak (1980) warm humid conditions, low temperature at night as well as increased wind velocity favors the progression and dispersion of disease. Additionally, a minimum temperature of 11-14 °C and a maximum of 27-31 °C having 64-72% relative humidity are favorable conditions for the development of disease (Gupta, 1979). However, conidial germination is maximum at 23 °C temperature with 20% relative humidity and grows its mycelium in three days, whereas, fungi complete its infection cycle within 9 days on vegetative shoots (Sinha et al., 2002; Singh, 2000).

7. Disease Losses

Disease losses generally depend on the region, time of infection, varieties, management strategies, and environmental factors. Estimated losses of powdery mildew range b/w 0.0 to 70% in different mango-producing areas of the world while on average 15-20% worldwide. The major disease losses are directly associated with blossom infection as compared to the foliage (Ruehle and Ledin, 1956; Lonsdale

Table 1. Previous investigations regarding the use of chemical fungicides against *Oidium Mangifera* causing powdery mildew of mango

Sr #	Active Compound	Trade Name	Mode of Action	Group of Researchers
1	Carbendazim	Bavistin	Inhibit DNA synthesis	Nasir et al. 2017
2	Thiophanate methyl	Topsin M	Curative action	Sinha and Verma 2002
3	Mancozeb	Dithan M-45	Disturb biochemical processes in fungi	Dalvi et al. 2021
4	Thiabendazole	Mintezol	Inhibit mitochondrial enzymes	Nasir et al. 2017
5	Copper oxychloride	Cupravit	Preventive action	Prakash and Raoof 1994
6	Zineb	Devizes	Preventive action	Chavan et al. 2009
7	Maneb	Farmaneb	Disrupt fungal biochemical process	McMillan 1973
8	Chlorothalonil	Daconil	It disrupts fungal cells	Kawate 1993
9	Ziram	Fungostop	Inhibit fungal growth	Prakash and Raoof 1994
10	Chlorothalonil	Bravo	It disrupts fungal cells	Kawate 1993
11	Benomyl	Benlate	Inhibit fungal growth	Chavan et al. 2009
12	Metiram+Pyraclostrobin	Cabrio top	It stops fungus growth	Nasir et al. 2017

and Kotze, 1993a). Under severe outbreaks of powdery mildew losses due to powdery mildew are reported 80-90% in Rhodesia and South Africa, 20% in Bombay (India), above 20% in Florida, and 20% in Multan (Pakistan) from 1990-1993.

8. Management Strategies for Powdery Mildew Disease

8.1. Chemotherapeutic Management of Powdery Mildew

A variety of synthetic chemicals are in practice against powdery mildew of mango in different mango-producing countries of the world. These chemicals include copper-based compounds like Bordeaux mixture and Copper Oxychloride solutions (Cobox, Vitigran and Cupravit) (Prakash and Raoof, 1994), Sulphur fungicides (Zineb, Maneb, Mancozeb, Thiram, Ziram, Ferbam and Nabam) (Desai, 1998; Prakash and Raoof, 1994), Chlorothalonil like Bravo and Daconil (Kawate 1993). Nitro compounds like Dinocap and Dapacryl (Datar, 1986; Gupta and Yadav, 1984) and systemic fungicides like Benzimidazole (Benomyl, Thiophanate Methyl, Carbendazim and Thiobendazole), Morpholines (Fenpropimorph and Tridemorph), Organophosphorus (Pyrazophous) and Pyrdimines (Dimethirimol and Bupirimate) (Chavan et al., 2009; Prakash and Raoof, 1994; Haq et al., 1994) (Table 1).

9. Eco-friendly Approaches for Disease Management

9.1. Antifungal activity of Bio-control Agents

The reducing efficiency of fungicides used against plant disease management as well as their residual effects on fruits have forced scientists and researchers to investigate new disease control strategies that are eco-friendly and safer. Moreover, Dag et al. (2001) reported that synthetic fungicides also affect fertility and pollen germination of mango plants. The use of bio-agents is the best alternative to synthetic chemicals. *Ampelomyces quisqualis* not only parasitized *Oidium mangifera* casing agent of mango powdery mildew but also tolerant to various fungicides used to manage the disease as indicated by Sztejnberg et al. (1989). Similarly, Nofal and Haggag (2006) described that *Verticillium lecanii*, *Tilletiopsis minor*, and *Bacillus subtilis* significantly inhibited fungal multiplication both under *in-vitro* and *in-vivo* conditions. Active compounds D-pinitol present in the stalk of soybean vegetables that are commonly treated as agricultural waste were found to be significantly prominent for the management of powdery mildew disease of cucumber. Future research is necessary to investigate their application as an economical phytochemical and potential bio-fungicide against the powdery mildew of mango.

Table 2. Previous studies regarding the potential use of phytoextracts against powdery mildew disease

Sr #	Phyto-extracts	Mode of action	Host plant	Group of researchers
1	Garlic	Inhibitory action	Mango, Cluster bean, Muskmelon	Alder and Beuchat 2002
2	Chilli	Inhibit fungal growth	Mango	Weber et al. 1992
3	Onion	Inhibitory action	Okra, Muskmelon and Cluster bean	Ashfaq et al. 2015
4	Neem	Inhibit radial growth	Okra, Neem and Ginger	Yousaf et al. 2016
5	Dhatura	Preventive action	Okra, sunflower,	
6	Rosemary	Inhibit radial growth	Sunflower	Abo-Elyousr et al. 2022
7	Jatropha	Inhibit mycelial growth	Sunflower	
7	Ginger	Cell death	Okra and Sunflower	Ashfaq et al. 2015
8	Tulsi	Inhibit fungal growth	Cluster bean	Abo-Elyousr et al. 2022
9	Turmeric	Cell death	Cluster bean	
10	Ardusi	Inhibit fungal growth	Cluster bean	
11	Lantana	Inhibit spore germination	Cluster bean	
12	Eucalyptus	Inhibition of cellular respiration	Muskmelon	Yousaf et al. 2016

Table 3. List of nanoparticles previously used against powdery mildew disease on different hosts

Sr #	Nanoparticles	Mode of Action	Host Plant	Group of Researches
1	AgNPs	Affects fungal cell wall	Cucumber	Lamsa et al. 2011
2	MgONPs	Not cleared	Pepper	Ismail et al. 2021
3	ZnONPs	Inhibit hyphal growth	Pepper	
4	TiO_2NPs	Inhibit mycelial growth of fungus	Mango	Farhat et al. 2018
5	SiO	Physical damage	Mango	
6	AgNPs	Affects fungal cell wall	Pumpkin	Lamsa et al. 2011
7	AgNPs	Affects fungal cell wall	Pea	Chowdhury et al. 2022
8	Silica NPs	Physical damage	Squash	Hateem et al. 2021

9.2. Antifungal Potential of Phyto-Extracts

The use of chemicals is highly recommended when disease appears in epidemic form but the continuous application of synthetic chemicals poses a serious threat to mankind, pollutes the environment and

cause Phyto-toxicity. That's why, it is need of time to investigate disease control strategies that are eco-friendly, cost-effective, and easily biodegradable. Schilder et al. (2002) and Yildirim et al. (2002) reported that various bio-control agents, phyto-extracts are in practice against powdery mildew of various greenhouse crops. Garlic has antimicrobial potential as allicin present in garlic has broad-spectrum biological activities against a variety of bacteria, fungi, viruses, and protozoa (Weber et al., 1992; Alder and Beuchat, 2002). Allicin and capsicum expressed the most effective antifungal activities against powdery mildew and sooty mold of mango as indicated by Alkolaly et al. (2022). Ashfaq et al. (2015) evaluated various plant extracts (Neem, Garlic, Ginger, Dhatura, Onion) against powdery mildew of okra and found that neem gave better control of disease under field conditions. Moreover, the antifungal potential of garlic, neem, ginger, eucalyptus, and onion was evaluated against powdery mildew of muskmelon (Yousaf et al., 2016). Extracts of *Rosmarinum officinalis* and *Datura stramonium* were used under greenhouse conditions against powdery mildew of

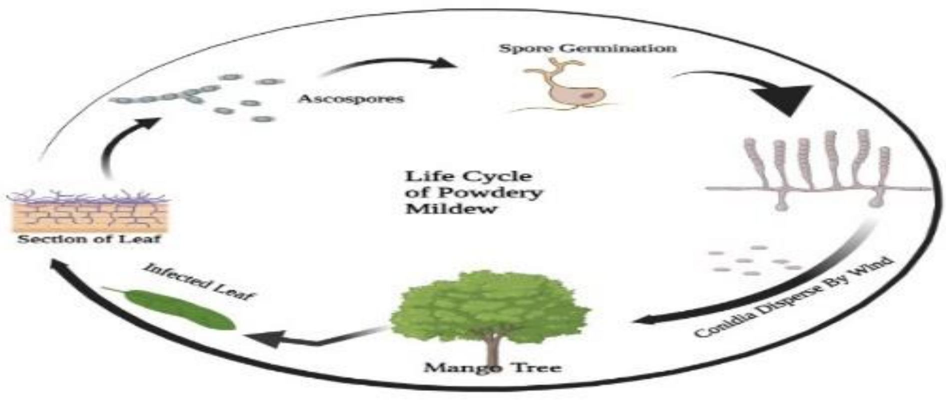

Figure 1. Disease cycle of Powdery Mildew of Mango

sunflower and *Datura stramonium* significantly reduced the severity percentage of the disease (Abo-Elyousr et al., 2022) (Table 2). Sangani et al. (2017) assessed nine Phyto extracts against powdery mildew of cluster beans and demonstrated that extracts of neem and jatropha provided the highest inhibition of spore germination under lab conditions.

10. Potential use of Nanotechnology

The application of chemicals is a quick, easy, and economically important way to combat plant disease problems but the continuous usage of synthetic chemicals tends to develop a resistance in pathogens towards fungicides. Therefore, there is a need for time to introduce ecologically acceptable techniques to fight pathological issues. Nanoparticles are eco-friendly, easily biodegradable, and are the best substitute for chemicals. Silver nanoparticles were evaluated against powdery mildew diseases under *In-vitro* and *In-vivo* conditions and findings indicated that the highest inhibition of fungal hyphae and conidial germination was seen when silver nanoparticles were applied @ 100 ppm (Lamsa et al., 2011). MgO and ZnONPs were used as a foliar spray against powdery mildew of pepper under greenhouse conditions and better results were found in the case of MgO-NPs (Ismail et al., 2021) (Table 3). Additionally, ZnO, titanium, silver, silicon, and Sulphur nanotechnology is in practice against the powdery mildew of peas, and cucumber as well as for powdery mildew of *Luffa cylindrica (*Chowdhury et al., 2022; Yang et al., 2022).

11. Conclusion and Recommendations

It is a need of time to pay attention to cutting-edge research areas such as pathotyping and forecasting models because of the complex and diverse nature of this pathogenic fungi. Many bio-control agents may not possess the ability to establish themselves in new habitats, making it necessary to conduct comprehensive field assessments of biocontrol strategies. Furthermore, due to the limited information available on the green nanotechnological approach, it becomes imperative to emphasize advanced research in this field to effectively combat this Phyto-pathological problem.

12. Acknowledgment

The authors are highly thankful to the Fungal Pathology Laboratory of Crop Diseases Research Institute (CDRI), National Agricultural Research Centre, Pakistan Agricultural Research Council Islamabad, Pakistan for technical assistance.

13. Conflict of interest

The Authors declare that there is no conflict of interest.

14. REFERENCES

Abo-Elyousr, K., H.A. Ahmed, M.A. Hassan and B.E.A. El-Fatah. 2022. Influence of foliar application of some salts, phyto-extracts, and essential oils for controlling powdery mildew disease of

Helianthus annuus. J. Plant Pathol. 104:735-747.

Adler, B.B. and L.R. Beuchat. 2002. Death of Salmonella, *Escherichia coli* O157:H7, and *Listeria monocytogenesin* garlic butter as affected by storage temperature. J. Food Prot. 65:1976-1980.

Akhtar, K.P., I.A. Khan, M.R. Kazmi, R.I. Hassan and B. Fatima. 1999. Preventive control of powdery mildew disease of mango. Sultan Qaboos Univ. J. Sci. Res. Agric. Sci. 4: 23-28.

Alkolaly, A.M., R.A. Hassan and G.A. Monir. 2022. Impact of powdery mildew and sooty mold diseases on mango by natural fungicide. Int. J. Sci. Res. Updates. 3:127-133.

Ashfaq, M., M. Atiq, S.T. Sahi, M. Younas, K. Ghafoor, M. Shafiq, M. Sajid, M.R. Bashir, S. Latif, I. Mubeen and M.U. Chatha. 2015. Management of powdery mildew of okra through plant extracts and chemicals under field conditions. Pak. J. Phytopathol. 27:163-168.

Bally, I.S. and N.L. Dillon. 2018. Mango (*Mangifera indica* L.) breeding. Adv Plant Breeding Strategies. Fruits. 3:811-896.

Braun, U. and R.T.A. Cook. 2012. Taxonomic Manual of the Erysiphales (Powdery Mildews). CBS Biodiversity Series, 11:1–707.

Briton, J.H.R. 1923. Mycological work in Egypt during the period 1920-22. Technical and Scientific Service Bull. Ministry of Agric. Egypt. 49:1-129.

Brodrick, H.T. 1971. Mango diseases. Farming in South Africa. 47:29-32.

Chowdhury, A.R., M.Z. Siddiqui, S. Maurya, C.J. Mate and M. Ali. 2022. Synthesis, characterization, and inhibition effects of Jhingan gum-induced silver nanoparticles against powdery mildew of pea. Ind. Phytopathol. 1-8.

Cunnington, J.H., S. Takamatsu, A.C. Lawrie and I.G. Pascoe. 2003. Molecular identification of anamorphic powdery mildews (Erysiphales). Aus. Plant Pathol. 32:421-428.

Dag, A., D. Eisenstein and S. Gazit. 2001. Effects of three fungicides used to control powdery mildew in Mango on pollen germination and pollen tube growth. Proc. Interim. Soc. Trop. Hortic. 43:123-126.

Dalvi, M.B., P.D. Patil, H.D. Pawar, R.A. Raut, S.S. Bhure and V.S. Desai. 2021. Efficacy of different bio-organics for the management of important diseases of mango (*Mangifera indica* L.). Crop Res. 56:308-312.

Datar, V.V. 1986. Management of powdery mildew of mango with fungicides. Indian Phytopathol. 39:271-272.

Desai, S.A. 1998. Tridemefon in the control of powdery mildew of mango. Karnataka J. Agric. Sci. 11(2).

Farhat, M.G., W.M. Haggag, M.S. Thabet and A.A. Mosa. 2018. Efficacy of silicon and titanium nanoparticles biosynthesis by some antagonistic fungi and bacteria for controlling powdery mildew disease of wheat plants. Technol. 14:661-674.

Felix, G.R., R.G. Herrera, V.C. Martínez, E.R.M. Longoria, M.I.E. Maldonado, F.F.R. Quiroz, A.J.C. Martínez, P.L.M. García and M.S. Espinosa. 2013. First report of powdery mildew (*Pseudoidium anacardii*) of mango trees in Sinaloa, Mexico. Plant Dis. 97(7):994-994.

Fields, W.S. 1945. Summary of the more important plant diseases taken in connection with the insect and plant disease survey in the general vicinity of the ports of entry from January 1945 to June 30, 1945. Plant Dis. Report. 29(11).

Galloway, L.D. 1935. Indian Soil fungi. Ind. J. Agric. Sci. 6:578-585.

Gupta, J.H. and A.S. Yadav. 1984. Chemical control of powdery mildew of mango. Indian J. Mycol. Plant Pathol, 14:297-298.

Gupta, J.H. 1979. Influence of environmental factors on the development of powdery mildew of mango. Ind J. Horti. 36:96-98.

Haq, A., M.T. Malik, S. Ali and S.H. Khan. 1994. Evaluation of various fungicides against powdery mildew of mango (*Oidium mangiferae*) in mango. Pak. J. Phytopathol. 6:17-20.

Hateem, M.W. and J. Khazal. 2021. Effectiveness of Foliar Spray and Root Treatment with Regular and Nanoparticle Silicon in Controlling Powdery Mildew on Squash in Greenhouse. Ind. J. Ecol. 17:399-402.

Ismail, A.M., A. El-Gawad and E. Mona. 2021. Antifungal activity of MgO and ZnO nanoparticles against powdery mildew of pepper under greenhouse conditions. Egyptian J. Agric. Res. 99:421-434.

Jiskani, M.M., M.A. Pathan, K.H. Wagan and M.I. Khaskheli. 2007. Documentation of identified and unidentified diseases of mango in Sindh, Pakistan. In: International symposium on prospects of horticultural industry in Pakistan. Institute of Horticultural Science, University of Agriculture Faisalabad, Pakistan. pp. 176-190.

Kawate, M. 1993. Pesticides registered for mango.

Kulkarni, G.S. 1924. Report of work done in the plant pathology section during the year 1922-23. Annual Report Agriculture Bombay Presidency for Year, 1922-23. pp. 167-171.

Kulkarni, V.M. and V.K. Rathod. 2014. Extraction of mangiferin from *Mangifera indica* leaves using three-phase partitioning coupled with ultrasound. Ind. Crop. Prod. 52:292-297.

Lamsa, K., S.W. Kim, J.H. Jung, Y.S. Kim, K.S. Kim and Y.S. Lee. 2011. Inhibition effects of silver nanoparticles against powdery mildew on cucumber and pumpkin. Mycobiol. 39:26-32.

Lonsdale, J.H. and J.M. Kotze. 1993. Chemical control of mango blossom diseases and the effect on fruit set and yield. Plant Dis. 77:558-562.

McMillan, Jr. R.T. 1973. Control of anthracnose and powdery mildew of mango with systemic and non-systemic fungicides. Trop. Agric. 50:245-248.

McRae, W. 1924. Economic botany part IV Mycology. Annual Report Board of Scientific Advice, India, 1922-23. pp. 31-35.

MNSFR. 2020. Fruit, vegetables and condiments statistics of Pakistan (2018–19). The Ministry of National Food Security & Research.

Mougou, A., C. Dutech and M.L. Desprez-Loustau. 2008. New insights into the identity and origin of the causal agent of oak powdery mildew in Europe. Forest Pathol. 38:275.

Naqvi, S.A.H., R. Perveen, S.A. Manzoor, H.M.I. Umar, M.T. Iqbal, F. Liaquat, T. Majid and A. Irshad. 2014. Evaluation of Various Mango Varieties against the Infection Dynamics of Powdery Mildew (*Oidium mangiferae* Bert.). American J. Plant Sci. 5:2372-2377.

Nasir, M., B. Iqbal, M. Idrees, M. Sajjad, M.Z. Niaz, H. Anwar, M.A. Shehzad and A.H. Tariq. 2017. Efficacy of some organic fungicides against anthracnose and powdery mildew of mango. Pak J. Agric. Sci. 54(3).

Nelson, S.C. 2008. Mango powdery mildew. Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa.

Nofal, M.A. and W.M. Haggag. 2006. Integrated management of powdery mildew of mango in Egypt. Crop Protec. 25:480-486.

Pathak, V.N. 1980. Diseases of fruit crops. Diseases of fruit crops. Oxford & IBH Publishing Co. New Delhi, India.

Pavithra, G., P. Alila, C.S. Maiti, A. Sarkar and A.K. Sahu. 2021. Effect of mineral boron sources on reproductive, yield, and quality characteristics of mango (Mangifera indica). Curr. Horti. 9:41-45.

Ploetz, R. 1999. Anthracnose is the most important disease in much of the mango-producing world. News Lett. Plant Pathol. 3:1-6.

Prakash, O. and M.A. Raoof. 1994. Studies on powdery mildew (Oidium mangiferae) disease of mango: Distribution, perpetuation, losses, and chemical control. Bio. Memoirs. 207:31-45.

Reichert, I. and J. Palti. 1951. Synopsis of the results obtained with sulfur and copper fungicides in plant disease control in Palestine. Available at: https://www.cabdirect.org/cabdirect/abstract/19521101645.

Rodriguez, L.A. and R.M. Figueroa. 1963. The appearance of Oidium or ash on mangoes in Venezuela. Rev. Fac. Agron. 3:40-47

Ruehle, G.D. and R.B. Ledin. 1956. Mango growing in the Florida Agricultural Experimental Station. Bulletin, pp.57.

Sangani, M.D., L.F. Akbari, S.V. Lathiya and C.M. Bhaliya. 2017. Antifungal Activity of Different Phytoextracts against Leveillula taurica Causing Powdery Mildew of Cluster Bean. Trend Biosci. 10:2422-2424.

Sattar, A. 1946. Diseases of mango in Punjab. Punjab Fruit J. 10:56-58.

Schilder, A.M., J. Gillett, R.W. Sysak, J. Wise and O. Fordergemeinschaft. 2002. Evaluation of environmentally friendly products for control of fungal disease of grapes. In: Tenth International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit Growing Viticulture, 4–7 February, Weinsberg, Germany.163-167.

Shah, K.A., M.B. Patel, R.J. Patel and P.K. Parmar. 2010. Mangifera indica (Mango). Pharmacogon. Rev. 4:42-48.

Singh, L.B. 1960. The mango. The mango. Leonard Hill Books Ltd., London.

Singh, R.S. 2000. Powdery mildew of mango. In: Diseases of fruit crops, Oxford & IBH Publishing, New Delhi. pp. 157-159.

Sinha, P., R. Prajneshu and A. Varma A. 2002. Growth models for powdery mildew development of mango. Ann. Plant Prot. Sci. 10:84-87.

Sinha, P. and A. Varma. 2002. Chemical management of mango powdery mildew. Ann. Plant Protec. Sci. 10:291-294.

Sztejnberg, A., S. Galper, S. Mazar and N. Lisker. 1989. Ampelomyces quisqualis for biological and integrated control of powdery mildews in Israel. J. Phytopathol. 124:285-295.

Tahir, W.A., M. Ahmad and M. Iftikhar. 2012. An analysis of the effectiveness of extension work conducted by the public sector with special reference to mango in southern Punjab, Pakistan. Pak. J. Agric. Sci. 49:229-232.

Uppal, B.N. 1937. Summary of work of Plant Pathologist, Bombay. Rep Dep Agric Bombay. 36:203-207.

Wager, V.A. 1937. Mango diseases in South Africa. South Africa, 12(4).

Wagle, P.V. 1928. Studies in the Shedding of mango flowers and fruits. Govt. of India, Central Publication Branch, Calcutta.

Weber, N.D., D.O. Andersen, J.A. North, B.K. Murray, L.D. Lawson and

B.G. Hughes. 1992. Invitro virucidal effects of Allium sativum (garlic) extract and compounds. Planta Med. 58:417-423.

Yadav, D. and S.P. Singh. 2017. Mango: History origin and distribution. J. Pharmacog. Phytochem. 6:1257-1262.

Yang, L., H. Chen, W. Yan, S. Huang D. Cheng, H. Xu and Z. Zhang Z. 2022. A pH-and redox-stimulated responsive hollow mesoporous silica for triggered delivery of fungicides to control downy mildew of Luffa cylindrica. Pest Manag. Sci. 78:3365-3375.

Yildirim, I., E. Onogur and M. Irshad. 2002. Investigations on the efficacy of some natural chemicals against powdery mildew [Uncinula necator (Schw.) Burr.] of grape. J. Phytopathol. 150:697-702.

Yousaf, S., M. Atiq, S.T. Sahi, I. Ahmad, L. Amrao, A. Jabbar, S.H. Khan, M. Asif and A. Subhani. 2016. Management of powdery mildew of muskmelon through chemicals and plant extracts. Pak. J. Phytopathol. 28:255-261.